WADC TECHNICAL REPORT 54-329

CHROMIZING OF TITANIUM CARBIDE CERMETS

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WRIGHT AIR DEVELOPMENT CENTER

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FOREWORD

This report was prepared by Richard L. Wachtell and Richard P. Seelig of Chromalloy Corporation, New York, New York. The report summarizes work done during the period from 1 September 1953 to 1 March 1954 in which research and development was conducted to alloy a chromium case to a nickel bonded titanium carbide cermet and to an iron bonded titanium carbide cermet. The work was accomplished under Contract No. AF 33(616)-2232; identified by Research and Development Order No. 506-67, Ceramic Components for Aircraft Power Plants. The work was administered under the direction of the Power Plant Laboratory, Directorate of Laboratories, Wright Air Development Center, with Lt. J. W. Ternent, Jr., acting as project engineer.

ABSTRACT

Ni-Mo bonded and Fe-Si bonded TiC cermets can be chromized.

The room temperature transverse rupture strength of these materials was found to be lower after chromizing. It was discovered that this drop in strength was primarily, if not entirely due to the heating cycle involved rather than the chromizing reaction itself.

The oxidation resistance of both compositions was markedly improved through chromizing by the CHROMALLOY process. The protective case is not disturbed by thermal cycling.

PUBLICATION REVIEW

FOR THE COMMANDER:

for

NORMAN C. APPOLD
Colonel, USAF
Chief, Power Plant Laboratory

Air Force

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2. Room Temperature Transverse Rupture Test

Room temperature transverse rupture testing was employed in order to check, in a preliminary way, on the effect of the chromizing treatment on the physical properties on these materials. Table 1 summarizes the transverse rupture data obtained.

Table I

Summary of Transverse Rupture Data

Condition	Mix 1590	K-163
AS RECEIVED	80,500	201,000
	77,900	216,500
	106,500	174,700
	111,200	137,700
	92,000	140,500
	100,500	166,000
HEATED IN INERT MATERIAL		
Kaolin for 12 hours at 1800°F.	82,000*	119,000*
Kaolin for 12 hours at 1950°F.	52,500	89,200
	102,800	79,500
Chromite for 12 hours at 1950°F.	67,000	77,800
	65,000	69,100
Al_2O_3 for 10 hours at 1850°F.	91,500	93,500
	90,500	101,500
Kaolin for 12 hours at 1800°F.	84,800	117,200
	79,200	120,200
CHROMIZED		
24 hours at 2000°F.	36,800	99,250
	36,800	92,000
	44,800	99,500
12 hours at 1800°F.	53,000**	1[illegible]7,000**
12 hours at 1950°F.	43,300	77,000
	42,900	78,700
	49,200	82,800
10 hours at 1850°F.	39,600	75,500
	38,600	78,500
12 hours at 1800°F.	55,200	196,500
	57,400	118,300
	47,500	106,500

* Average of 2 values

** Average of 3 values

NOTE: All other values are individual values.

In this Table, the strengths of specimens chromized at four different temperatures are compared with as-received specimens. In addition, some specimens were heated to the same temperatures and for the same lengths of time in inert powders. Several conclusions may be drawn from the data shown (note that these conclusions may apply only to the specific compositions, heating cycles and test conditions used):

a. There is a considerable variation in the transverse rupture strength from specimen to specimen even in the as-received condition.

b. Chromizing of Fe-Si bonded TiC (Mix 1590) causes a serious drop in strength. However, heating in three different inert powders causes a similar, but less severe drop.

c. Chromizing of Ni-Mo bonded TiC (K-163) also results in a severe decrease in strength. However, by heating in inert powders to the same time/temperature cycles a comparable reduction in the modulus of rupture is induced.

d. The Fe-Si bonded composition (Mix 1590) seems to be somewhat less sensitive to heating in inert powder and more sensitive to actual chromizing.

e. The Ni-Mo bonded cermet (K-163) lost a proportionately greater amount of strength due to the heating cycle in inert powder. This loss seems to be about the same regardless whether chromizing takes place or not.

3. Oxidation and Heat Shock Tests

The first oxidation tests were of an exploratory nature as a means of evaluating the effect of chromizing. Comparative oxidation tests were performed in a gasoline burner with the following results:

a. One sample of each material (CHROMALLOY SXP 363) was broken after chromizing. Thus, each specimen had one exposed surface. They were heated to an average temperature of 2050°F. for 3 hours, with occasional overshoots to 2300°F. No attack was noted on the K-163 (Ni-Mo binder) composition. There appeared some attack on the fractured (exposed) surface of the Mix 1590 (Fe-Si binder) material.

b. One sample of each material, processed in CHROMALLOY Experiment XP 258, was broken after chromizing. Again, each specimen thus had one exposed surface. This test was run for approximately 4 hours at an average temperature of 2000°F. In order to accelerate the test, the temperature was then raised to 2300°F. for an additional 14 1/2 hours. Some oxide flaking was observed on the exposed (not chromized) surface of the Ni-bonded (K-163) specimen after the first (lower temperature)

test period. The chromized surface was nice and smooth. After completion of the entire test period, both specimens showed evidence of oxidation attack on the uncoated surface. The oxidation product could readily be scraped off to a considerable depth by means of a pen knife. The chromized surfaces, on the other hand, although they had lost their smooth appearance, retained their original form and sharp corners. The case was hard and could not be removed in the above-mentioned manner. The general appearance of the chromized surface after this test was superior for the Fe-Si bonded cermet (Mix 1590), although in the as-chromized condition, the Ni-Mo bonded composition has a smoother surface.

c. A comparison was made between two whole specimens of the K-163 composition (Ni-Mo binder). One was tested in the as-received condition and the other one after CHROMALLOYING in Run XP 245. The test was carried out within a temperature range of 1600 to 2300°F; most of the time the specimens were at about 2100°F. The total time was 14 1/2 hours. After the test, the as-received specimen had gained 0.15 gr., while the CHROMALLOYED specimen had gained only 0.05 gr. The total specimen weight was approximately 7 gr. in each case.

From these first tests, it appeared that the oxidation resistance of these titanium carbide specimens improved by virtue of the CHROMALLOY case. Thus, it was decided to look into this feature further, especially in connection with lower chromizing temperatures. Additional oxidation test observations are summarized in Table II.

Table II

Oxidation Test Results on CHROMALLOYED Cermets

Specimens: Broken modulus of rupture bars
Test Conditions: 1900°F. approximately 14 hours in combusted city gas with excess oxygen

Results:

Type 1590 (Fe-Si bonded titanium carbide)

Unprotected surface was covered with a rust-colored powdery oxide. Attacked layer was fairly deep in the order of .0X in. Oxide can be scraped off rather easily. Some swelling was observed at the edges.

CHROMALLOYED surface was covered with a blackish tarnish. This layer cannot be scraped off and appears to be tenacious. No change in configuration occurred.

Type K-163 (Ni-Mo bonded titanium carbide)

Unprotected surface showed a blistery appearance. The layer was of purplish-black color and could be scraped off with some difficulty. It was in the order of .0X in. deep. Some swelling was observed at the edges.

CHROMALLOYED surface was identical to the one described for Type 1590 cermet.

Heat shock tests were performed at the WADC Power Plant Laboratory on ten nozzle diaphragm vanes. The following results were obtained:

Table III

Type of Carbide	Treatment	Total cycles	Remarks
	A. Tested as Received		
Mix 1590	CHROMIZED (XP 392)*	1000	No cracks, no erosion, no warping.
Mix 1590	Not chromized (XP 390)**	1000	Cracked after 140 cycles, brown oxide.
K-163	CHROMIZED (XP 392)	1000	Cracked after 60 cycles, no warping or erosion.
K-163	Not chromized (XP 390)	1000	Cracked after 220 cycles.
	B. Heated to 1650 F for 100 hrs., then tested		
Mix 1590	CHROMIZED (XP 392)	960	Broke, no erosion
Mix 1590	CHROMIZED (XP 392)	1000	Cracked after 40 cycles.
Mix 1590	Not chromized (XP 390)	1000	No cracks; surface badly oxidized.
K-163	CHROMIZED (XP 392)	640	Broke, no erosion.
K-163	CHROMIZED (XP 392)	300	Broke, no erosion.
K-163	Not chromized (XP 390)	240	Broke, oxidized.

* Process XP 392 - Chromized for 10 hours at 1850°F.
** Process XP 390 - Heated in Al_2O_3 powder for 10 hours at 1850°F.

The conclusions which may be drawn from the data in Tables II and III are:

a. Chromizing improves the oxidation resistance of both types of TiC cermets.

b. This improvement in oxidization resistance is apparent not only in the outer flame tests, but also in the heat shock tests. Thus, the protective case is not disrupted by thermal cycling.

c. The results of the heat shock test itself are inconclusive. Unfortunately, no vanes in the as-received condition were available for comparison purposes. It cannot, at this point, be stated definitely whether chromizing and heating in inert powders improve or impair the heat shock resistance.

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